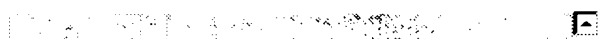


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116 and nanofiltration

16





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1. Document ID: US 5858240 A

File: USPT

Jan 12, 1999

L11: Entry 1 of 3

US-PAT-NO: 5858240

DOCUMENT-IDENTIFIER: US 5858240 A

TITLE: Nanofiltration of concentrated aqueous salt solutions

DATE-ISSUED: January 12, 1999

INVENTOR INFORMATION:

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COUNTRY

CAX

CAX

US-CL-CURRENT 210/652; 210/639, 210/641, 210/651, 210/653, 210/805

Full	Title	Citation	Front	Review	Classification	Date	Reference	Claims	KWIC	Draw Desc	Image
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2. Document ID: US 5587083 A

File: USPT

Dec 24, 1996

L11: Entry 2 of 3

US-PAT-NO: 5587083

DOCUMENT-IDENTIFIER: US 5587083 A

TITLE: Nanofiltration of concentrated aqueous salt solutions

DATE-ISSUED: December 24, 1996

INVENTOR INFORMATION:

NAME

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CITY

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STATE

ZIP CODE

COUNTRY

CAX

US-CL-CURRENT: 210/652; 210/651, 210/653

Full	Title	Citation	Front	Review	Classification	Date	Reference	Claims	KWIC	Draw Desc	Image
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3. Document ID: US 5147553 A

File: USPT

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L11: Entry 3 of 3



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ABSTRACT: Electrolysis processes using one or more conventional electrochemical cells and membranes under a constant applied pressure is used to selectively transfer the concentration of one solute, such as sodium chloride or sodium chlorate, providing monovalent ions, from another solute such as sodium sulfate or sodium dichromate to provide multivalent ions in high salt aqueous concentrations. The process is particularly useful in favorably lowering the concentration of undesirable ions, particularly, of sulfur and dichromate ions in chloralkali and chlorate brine containing solutions and favorably raising the sodium sulfate level relative to sodium chloride in chloralkali liquor.

ESPR:  
This invention relates to a process for reducing the concentration of undesirable compounds, particularly, solutes, in aqueous solutions by nanofiltration using a filtration membrane. More particularly, it relates to the substantial removal of sulfate, dichromate, phosphate, mercury, calcium, magnesium, aluminium, fluoride and silica monovalent and divalent ions from brine solutions, optionally, containing chlorate.

BSPR: Pressure driven membrane separation processes are known wherein organic molecules or inorganic ionic solutes in aqueous solutions are concentrated or separated to various degrees by the application of a positive osmotic pressure to one side of a filtration membrane. Examples of such pressures are reverse osmosis (RO), ultrafiltration (UF) and nanofiltration (NF). These pressure driven membrane processes employ a cross-flow mode of operation wherein only a portion of a feed solution (F) is collected as a permeate solution (P) and the rest is called "retentate" or a pass solution (C). In this specification and claims, the exit process stream from the nanofiltration module, which stream has not passed through the membrane is referred to as the "pass stream". This stream is often referred to by practitioners in the membrane filtration art as the "concentrate" stream.

BSFR  
Nanofiltration membranes are structurally very similar to reverse osmosis membranes in that chemically, they, typically, are crosslinked aromatic polyamides, which are cast as a thin "skin layer", on top of a microporous polymer sheet support to form a composite membrane structure. The separation properties of the membrane are controlled by the pore size and electrical charge of the "skin layer". Such a membrane structure is usually referred to as a thin film composite (TFC). However, unlike RO membranes, the NF membranes are characterized in having a larger pore size in its "skin layer" and a net negative electrical charge inside the individual pores. This negative charge is responsible for rejection of anionic species, according to the anion surface charge density. Accordingly, divalent anions, such as  $\text{SO}_4^{2-}$ ,  $\text{Cl}^-$ , and  $\text{CO}_3^{2-}$ , are strongly rejected than monovalent ones, such as  $\text{Cl}^-$ ,  $\text{NO}_3^-$ . Commercial NF membranes are available from known suppliers of RO and other pressure drive membranes. Examples include: Desal-5 membrane (Desalination Systems, Escondido, Calif.), NF20, NF50, NF40 and NF40HF membranes (FilmTec Corp., Minneapolis, Minn.), SW membrane (Toray, Japan), and NRT 7450 and NTR 7250 membranes (Nitto Electric, Japan). The NF membranes are, typically, packaged as membrane modules. A so-called "spiral wound" module is most popular, but other membrane module configurations, such as tubular membranes enclosed in a shell or plate-and-frame type, are also known.

BSFR:

Nanofiltration membranes have been reported to show no or little rejection of low molecular weight organic molecules, such as, methanol, ethanol and ethyleneglycol, but a significant rejection of higher molecular weight organic species, such as glucose. Among inorganic ionic solutes, low to medium rejection has been reported for simple 1:1 electrolytes, such as NaCl or NaNO<sub>3</sub>, and high rejection of other electrolytes where multivalent ionic species are involved, such as Na<sub>2</sub>SO<sub>4</sub>, SO<sub>4</sub>, MgCl<sub>2</sub> and FeCl<sub>3</sub>. Such a characteristic differentiates NF from RO which rejects all ionic species, and from ultrafiltration UF, which does not reject ionic species and only rejects organic compounds with molecular weights, typically, in excess of 1,000 g/mol.

BSFR:

During the NF process, a minimum pressure equal to the osmotic pressure difference between the feed pass liquor on one side and the permeate liquor on the other side of the membrane must be applied since osmotic pressure is a function of the ionic strengths of the two streams. In the case of separation of a multivalent solute, such as Na<sub>2</sub>SO<sub>4</sub>, from a monovalent one, such as NaCl, the osmotic pressure difference is moderated by the low NaCl rejection. Usually, a pressure in excess of the osmotic pressure difference is employed to achieve practical permeate flux. In view of lower NaCl rejection, NF has been used successfully for removal of sulfate and the hardness cations, Ca<sup>2+</sup> and Mg<sup>2+</sup> from brackish waters and even seawater, without the necessity to excessively pressurize the feed stream. The reported typical pressure range for NF is 80 to 300 psi, although membrane elements are designed to withstand pressures of up to 1,000 psi.

BSFR:

Reported uses of NF include the aforesaid water softening, removal of dissolved multivalent ions such as Ca<sup>2+</sup>, reduction of silica as a part of feedwater conditioning for a subsequent RO step or removal of medium molecular weight organic compounds. It has also been demonstrated that high rejection of ionic species could be obtained by proper conditioning of the stream, i.e. by changing its pH. Thus, effective removal (rejection) of carbonate anion could be achieved by adjusting the pH of the feed solution to about 12, to ensure that carbonate would predominantly exist as CO<sub>3</sub><sup>=</sup>, which anion is more strongly rejected by the NF membrane than the HCO<sub>3</sub><sup>-</sup> anion.

BSFR:

Dissolved or suspended silica in brine feed for chloralkali processes, especially the so-called membrane chloralkali process, presents a problem in that the silica forms scale on the surface or in the interior of the ion exchange membrane separator. This causes the cell voltage and, hence, power consumption to increase. In general, in the membrane chloralkali process, the concentration of silica in the feed brine should not exceed 10 ppm, although even a lower level may be needed if some other contaminants, such as Al<sup>3+</sup>, are present, since these contaminants enhance the scaling capacity of silica.

BSFR:

Use of strongly basic anion exchange membranes for silica removal from feedwater has been reported. However, the literature also recognizes that, in that case since there is a substantial background of other salts, the selectivity of the IX resin towards silica is greatly reduced.

BSFR:

Recent literature from FilmTec Corp., Minneapolis, Minn., describes the removal of silica from feedwater with a NF70 nanofiltration membrane, as part of a pretreatment for a subsequent RO step. A rejection of silica concentration in feedwater from 400 ppm to 50-60 ppm has been mentioned. The literature is silent, however, on the use of NF methods for silica removal from higher concentration salt solutions, such as chloralkali brine.

BSFR:

In a related chemical process, chlorine and caustic soda are prepared in an electrolytic cell, which contains a membrane to prevent chlorine and caustic soda reacting and the separated chemicals are removed.

BSFR:

sulfate ion is a common ingredient in commercial salt. When such salt is used directly, or in the form of a brine solution, and specific steps are not taken to remove the sulfate, the sulfate enters the electrolytic system. Sulfate ion maintains its identity under the conditions in the electrolytic system and, thus, accumulates and progressively increases in concentration in the system unless removed in some manner. In chlorate plants producing a liquor product, the sulfate ion will leave with the product liquor. In plants producing only crystalline chlorate, the sulfate remains in the mother liquor after the crystallization of the chlorate, and is recycled to the cells. Over time, the concentration of sulfate ion will increase and adversely affect electrolysis and cause operational problems due to localized precipitation in the electrolytic cells. Within the chloralkali circuit, the sodium sulfate will concentrate and adversely affect the membrane, which divides the anolyte brine from the catholyte caustic soda.

BSIR:

Accordingly, in its broadest aspect the invention provides in a nanofiltration process for filtering an aqueous liquor comprising feeding a feed liquor to a nanofiltration membrane module under a positive pressure to provide a pass liquor and a permeate liquor for selectively changing the concentration of a first compound relative to the concentration of a second compound in said aqueous liquor wherein said first compound has a first feed concentration and said second compound has a second feed concentration, said process comprising feeding said aqueous liquor to said nanofiltration membrane module, collecting said pass liquor wherein said first compound is at a first pass concentration and said second compound is at a second pass concentration, and collecting said permeate liquor wherein said first compound has a first permeate concentration and said second compound is at a second permeate concentration, the improvement comprising said first compound having a first concentration of greater than 50 g/l.

BSPR:

We have discovered that, for example, subjecting a concentrated sodium chloride-sodium sulfate solution to the NE process results in a very strong positive rejection of sodium sulfate by the membrane, but only a weak positive to negative rejection of the sodium chloride. Surprisingly, we have found that with increasing concentration of sodium sulfate in the feed liquor, the rejection of sodium chloride decreases and eventually becomes negative. However, sodium chloride rejection need not be negative in that the NaCl concentration in the permeate may be slightly lower than that in the feed. The pronounced influence of Na.sub.2 SO.sub.4 concentration in the feed on NaCl rejection values is most surprising.

BSPR:

Thus, surprisingly we have found that nanofiltration membrane processes can be used to beneficially reduce the concentration of multivalent ions, such as SO.sub.4<sup>2-</sup>, CrO.sub.4<sup>2-</sup> or Cr.sub.2 O.sub.7<sup>2-</sup> and dissolved silica in concentrated solutions of sodium chloride, such as brine, and concentrated sodium chlorate process liquors, wherein the main components are sodium chlorate and sodium chloride.

BSPR:

We have most surprisingly found, notwithstanding the teachings that commercially available nanofiltration membranes have a monocharged anion rejection property, e.g. a Cl<sup>-</sup> ion rejection in the range 20-50%, that such membranes when used with concentrated salt solutions exhibit no Cl<sup>-</sup> ion rejection. This unexpected absence of chloride rejection by the nanofiltration membrane has a significant practical importance in minimizing the osmotic pressure across the membrane and hence the energy required for pressuring the feed to achieve a given permeate flow. Further, in surprising contrast, the rejection of multivalent ions, such as SO.sub.4<sup>2-</sup>, CrO.sub.4<sup>2-</sup> or Cr.sub.2 O.sub.7<sup>2-</sup> and, also, silica, remains high.

BSPR:

Accordingly, such unexpected ion membrane selectivity at relatively high salt concentrations offers attractive applications such as, for example, in the treatment of chloralkali brine liquors having sodium sulfate levels unacceptable in recycle systems. As illustrated in an application of sulfate removal from brine, because there is no buildup in concentration of sodium chloride in the pass liquor stream over its original level in the feed stream, it is possible

increase the content of sodium sulfate in the pass liquor to a higher level than would have been possible if the NaCl level of the pass liquor had increased. Accordingly, it is now possible to realize a desirable high % Recovery, and, in the case of chloralkali brine, to minimize the volume of brine going into the side of a reactor and the amount of chemicals for an optional "side stream" sulfate precipitation step.

BSIR:

The processes of the invention are applicable as either single stage unit, or processes with optional recycle of either pass liquor or permeate liquor to the nanofiltration membrane module, or as part of a multi-stage, multi-module system.

BSPV:

The process of the invention as hereinabove defined may be operated at any suitable and desired temperature selected from subdegree C. to the boiling point of the feed liquor; and positive pressures applied to the feed side, generally selected from 50-1200 psi.

BSPV:

(a) Desal-5 Membrane Product Application Note, publication of Desalination Systems, Inc. (Escondido, Calif.), April 1991, wherein the Figure on page E-19.3 shows NaCl rejection in the 85 to 88% range.

BSPV:

(b) NT70 Membrane, Product Specification, publication of Filmed Corp. Minneapolis, Minn., cites Rejection of 60%; and

BSPV:

(c) "Membrane Handbook", ed. By W. S. W. Ho and K. K. Sirkar, Van Nostrand Reinhold, N.Y. 1992 at Table 23.2. "Characteristics of Selected Nanofiltration Membranes", cites NaCl % Rejection of: 80% for NF50 membrane (Filmed), 48% for NF40 membrane (Filmed), 50% for NTF-7250 membrane Nitto, 47% for Desal-5 membrane (Desalination Systems), and 55% for SU200HF membrane Toray.

DRPR:

FIG. 1 represents a diagrammatic flow sheet of a single stage membrane nanofiltration system of use in a process according to the invention; and

DRPR:

FIG. 2 represents a diagrammatic flow sheet of a multistage membrane nanofiltration system of use in a process according to the invention.

DEPR:

FIG. 1 shows generally as 10, a single stage membrane nanofiltration system for the separation of, for example, solute A from solute B in an aqueous liquor. System 10 comprises a feed solution holding tank 12 connected to a nanofiltration membrane module 14 by a feed conduit 16 through a high pressure pump 18 (Model I-2401, CIB Pumps Inc.). Module 15 comprises a single spiral wound type nanofiltration module containing Desal-5, DL2540 polyamide membrane 20 having 2.5 m.sup.2 of active membrane area. Exiting module 14 is a pass liquor conduit 22 having a pressure control valve 24 and a permeate liquor conduit 26.

DEPR:

The process depicted in FIG. 1 represents a single stage or batch-type process, wherein the pass liquor or the permeate liquor may be of sufficient and desired quality for use in a subsequent process or discharge. However, each of the pass and permeate streams, optionally, individually, may be sent through a nanofiltration membrane process again, in one or more cycles. In either a batch or continuous process. In industrial processes of use in the practice of the invention, the pass stream from the first stage may be sent to the second stage to increase the overall % Recovery. Alternatively, the NF process may be conducted in a batch mode with the pass liquor recycled back to the feed tank. Accordingly, in consequence, the feed composition will vary with time as will the Membrane Flux and possibly the % Rejection.

DEPR:

FIG. 2 represents a multi-stage NF method for the purification of brine by removal of sodium sulfate, according to the invention, wherein a plurality of NF



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pressure on the feed side was adjusted to 250-300 psi and kept constant during the run. Permeate and pass liquor streams were collected and analyzed over a period of 30 minutes. In total, 20.1 g/l permeate liquor and 1.1 g/l pass liquor were collected, while about 44 g/l feed solution remained in the tank at the end of the run. The calculated average permeate liquor and pass liquor flows were 0.12 lpm and 0.11 lpm, respectively. Subsequent chemical analysis revealed that the permeate liquor had 198 g/l NaCl, sub.3, 101.3 g/l NaCl, 4.1 g/l Na.sub.2 SO.sub.4, and 2.1 g/l Na.sub.2 SO.sub.4, while the pass stream had 381 g/l NaCl, sub.3, 96 g/l NaCl, 44.1 g/l Na.sub.2 SO.sub.4 and 1.1 g/l Na.sub.2 SO.sub.4. Calculated NF membrane % Rejections were: 99.8% for NaCl, 99.7% for NaCl, sub.3, 99.9% for Na.sub.2 SO.sub.4 and 99.9% for Na.sub.2 SO.sub.4.

DEPR:  
The following examples 4-6 further demonstrate the range of NaCl rejection during NF membrane treatment of NaCl-Na.sub.2 SO.sub.4 solutions.

DEPR:  
A batch of 80 liters of feed brine solution composed of 189.2 g/l NaCl and 11.4 g/l of Na.sub.2 SO.sub.4 was passed to the NF rig. Under an applied pressure of 288 psi, 10 liters of permeate liquor were collected, which represents 12.5% recovery. The permeate had a composition of 177.9 g/l NaCl and 0.16 g/l Na.sub.2 SO.sub.4. The calculated rejections were: 99.8% for NaCl and 99.8% for Na.sub.2 SO.sub.4, respectively.

DEPR:  
A batch of 80 liters of feed brine solution composed of 184.2 g/l NaCl and 11.4 g/l of Na.sub.2 SO.sub.4 was passed to the NF rig. Under an applied pressure of 302 psi, 28 liters of permeate liquor were collected, which represents 38% recovery. The permeate had a composition of 186.7 g/l NaCl and 0.2 g/l Na.sub.2 SO.sub.4. The calculated rejections were: 99.8% for NaCl and 99.8% for Na.sub.2 SO.sub.4, respectively.

DEPR:  
A batch of 80 liters of feed brine solution composed of 179 g/l NaCl and 71.3 g/l of Na.sub.2 SO.sub.4 was passed to the NF rig. Under an applied pressure of 648 psi, 9 liters of permeate liquor were collected, which represents 11.2% recovery. The permeate had a composition of 196.0 g/l NaCl and 0.9 g/l Na.sub.2 SO.sub.4. The calculated rejections were: 99.7% for NaCl and 99.8% for Na.sub.2 SO.sub.4, respectively.

DEPR:  
A batch of 80 liters of feed brine solution composed of 9.9 g/l NaCl and 87.5 g/l of Na.sub.2 SO.sub.4 was passed to the NF rig. Under an applied pressure of 515 psi, 9.6 liters of permeate liquor were collected, which represents 12% recovery. The permeate had a composition of 18.4 g/l NaCl and 2.4 g/l Na.sub.2 SO.sub.4. The calculated rejections were: 99.8% for NaCl and 99.8% for Na.sub.2 SO.sub.4, respectively.

DEPR:  
A batch of 80 liters of feed brine solution having a NaCl concentration of 288.9 g/l, pH 3, and spiked with 2.9 ppm F.sup.- was passed to the NF rig. Under an applied pressure of 501 psi, 8.6 liters of permeate liquor were collected, which represents 10.7% recovery. The permeate had a composition of 281 g/l NaCl and 2.9 ppm F.sup.-. The calculated rejections were: 99.8% for NaCl and 99.8% for F.sup.-, respectively.

DEPR:  
A batch of 80 liters of feed brine solution having a NaCl concentration of 288.9 g/l, pH 3, spiked with 3.2 ppm F.sup.- and 1.5 ppm Fe.sup.+, was passed to the NF rig. Under an applied pressure of 548 psi, 8.9 liters of permeate liquor were collected, which represents 11% recovery. The permeate had a composition of 281 g/l NaCl and 2.5 ppm F.sup.-. The calculated rejections were: 99.8% for NaCl and 99.8% for F.sup.-, respectively.

DEPR:  
A batch of 80 liters of feed brine solution having a NaCl concentration of 288.9 g/l, pH 3, spiked with 3.1 ppm F.sup.- and 2 ppm Fe.sup.+, was fed to the NF rig. Under an applied pressure of 557 psi, 8.9 liters of permeate liquor were

collected which represents 1.5% recovery. The permeate contained 1.0 g/l NaCl and 2.0 ppm Fe.supp.+. The calculated rejections were 99.5% for NaCl and 99.5% for Fe.supp.+, respectively.

**DEPR:**

A batch of 80 liters of feed sulphate brine solution containing 4.0 g/l NaCl and 0.00013 and 0.00014 g/l NaCl at a pH 1.5, was passed to the NF rig. Under an applied pressure of 575 psi, 7.9 liters of permeate liquor were collected which represents 9.9% recovery. The permeate contained 1 g/l NaCl and 0.00013 and 0.00014 g/l NaCl. The calculated rejections were 99.5% for NaCl and 99.5% for NaCl, respectively.

**DEPR:**

A batch of 80 liters of feed sulphate brine solution containing 4.0 g/l NaCl and 0.00013 and 0.00014 g/l NaCl at a pH 1.5, was passed to the NF rig. Under an applied pressure of 575 psi, 7.9 liters of permeate liquor were collected which represents 9.9% recovery. The permeate contained 1 g/l NaCl and 0.00013 and 0.00014 g/l NaCl. The calculated rejections were 99.5% for NaCl and 99.5% for NaCl, respectively.

**DEPR:**

This example demonstrates the efficacy of the NF method for removal of Al.supp.+ from brine.

**DEPR:**

A batch of 80 liters of feed brine solution containing 249.2 g/l NaCl and 1.5 ppm Al.supp.+ was passed to the NF rig. Under an applied pressure of 461 psi, 2.6 liters of permeate liquor were collected, which represents 3.3% recovery. The permeate contained 245.7 g/l NaCl and about 1 ppm Al.supp.+. The calculated rejections were: 1.4% for NaCl and 90.5% for Al.supp.+, respectively.

**DEPR:**

This example demonstrates the efficacy of the NF process for the removal of mercury from brine.

**DEPR:**

A batch of 80 liters of feed brine containing 249.2 g/l NaCl and 1.0 ppm Hg.supp.++ was passed to the NF rig. Under an applied pressure of 465 psi, 2.6 liters of permeate liquor were collected, which represents 3.3% recovery. The permeate contained 244.8 g/l NaCl and 7.1 ppm Hg.supp.++. The calculated rejections were: 1.5% for NaCl and 29% for Hg.supp.++, respectively.

**DEPR:**

Examples 17-21 demonstrate the efficacy of the NF method for the removal of Ca.supp.++ and Mg.supp.++ from brine and the effect of pH and brine strength thereon.

**DEPR:**

A batch of 80 liters of feed brine containing 288.7 g/l NaCl and 100 ppm Ca.supp.++ at a pH of 7.8 was passed to the NF rig. Under an applied pressure of 295 psi, 9.5 liters of permeate liquor were collected, which represents 11.9% recovery. The permeate contained 282.5 g/l NaCl and 87.5 ppm Ca.supp.++. The calculated rejections were: 2.3% for NaCl and 12.5% for Ca.supp.++, respectively.

**DEPR:**

A batch of 80 liters of feed brine containing 288.7 g/l NaCl and 100 ppm Ca.supp.++ at a pH of 2.0 was passed to the NF rig. Under an applied pressure of 301 psi, 9.5 liters of permeate liquor were collected, which represents 11.9% recovery. The permeate contained 285 g/l NaCl and 87.5 ppm Ca.supp.++. The calculated rejections were: 2.2% for NaCl and 29% for Ca.supp.++, respectively.

**DEPR:**

A batch of 80 liters of feed brine containing 288.7 g/l NaCl and 100 ppm Ca.supp.++ at a pH of 2.0 was passed to the NF rig. Under an applied pressure of 301 psi, 9.5 liters of permeate liquor were collected, which represents 11.9% recovery. The permeate contained 285 g/l NaCl and 87.5 ppm Ca.supp.++. The calculated rejections were: 2.2% for NaCl and 29% for Ca.supp.++, respectively.

**DEPR:**

Example 1: A batch of 80 liters of feed brine containing 285 g/l NaCl and 14 g/l K.sub.2 SO.sub.4 was passed to an NF rig. Under an applied pressure of 27 psi, 14 liters of permeate liquor were collected, which represents 17.5% recovery. The permeate contained 217.5 g/l NaCl and 1.4 g/l K.sub.2 SO.sub.4. The calculated rejections were 99.5% for NaCl and 99.1% for K.sub.2 SO.sub.4, respectively.

REIR:

Examples 21 and 22 demonstrate the efficacy of the NF treatment with respect to the separation of K.sub.2 SO.sub.4 from KCl and KBr brines.

REIR:

Example 21: A batch of 80 liters of feed brine containing 285 g/l KCl and 14 g/l K.sub.2 SO.sub.4 was passed to the NF rig. Under an applied pressure of 27 psi, 14 liters of permeate liquor were collected, which represents 17.5% recovery. The permeate contained 217.5 g/l KCl and 1.4 g/l K.sub.2 SO.sub.4. The calculated rejections were 99.5% for KCl and 99.1% for K.sub.2 SO.sub.4, respectively.

REIR:

Example 22: A batch of 80 liters of feed brine containing 285 g/l KBr and 14 g/l K.sub.2 SO.sub.4 was passed to an NF rig. Under an applied pressure of 27 psi, 14 liters of permeate liquor were collected, which represents 17.5% recovery. The permeate contained 242.4 g/l KCl and 1.4 g/l K.sub.2 SO.sub.4. The calculated rejections were 97.1% for KBr and 97.1% for K.sub.2 SO.sub.4, respectively.

CLAIM:

1. In a nanofiltration process for filtering liquor comprising feeding feed liquor to a nanofiltration membrane module under a positive applied pressure to provide a pass liquor and a permeate liquor for selectively changing the concentration of a first compound relative to the concentration of a second compound in said aqueous liquor, wherein said first compound has a first feed concentration and said second compound has a second feed concentration, the process comprising feeding said aqueous liquor to said nanofiltration membrane module, collecting said pass liquor wherein said first compound is at a first pass concentration and said second compound is at a second pass concentration, and collecting said permeate liquor wherein said first compound has a first permeate concentration and said second compound is at a second permeate concentration, the improvement comprising said first compound having a first feed concentration of greater than 50 g/L; the ratio of the first feed compound concentration to the second feed compound concentration in the permeate liquor increases and in the pass liquor decreases relative to their ratio in the feed liquor; and wherein said first feed compound contains monovalent ions and said second feed compound contains divalent trivalent ions.

CLAIM:

9. A process as defined in claim 1 further comprising feeding said pass liquor to one or more nanofiltration membrane modules connected in series so as to produce a second pass liquor and subsequent pass liquors, consecutively.

CLAIM:

10. A process as defined in claim 1 further comprising feeding said permeate liquor to one or more nanofiltration membrane modules connected in series so as to produce a second permeate liquor and subsequent permeate liquors, consecutively.

CLAIM:

11. A process as defined in any one of claims 1, 9 or 10, wherein said pass liquor or said permeate liquor is recycled back to one or more of said nanofiltration membrane modules.

REIR:

Desalination System, Inc. Escondido, CA, Apr. 1991, "Desal-8 Membrane Product Application Note".

REIR:

"Membrane Handbook", Ed. by W.S.W. Ho and F.K. Sirkar, Van Nostrand Reinhold, New York, 1991.

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114: Entry 1 of 4

File: USPT

Dec 2, 1997

US-PAT-NO: 5691237

DOCUMENT-IDENTIFIER: US 5691237 A

TITLE: Catalyst mediated method of interfacial polymerization on a microporous support, and polymers, fibers, films and membranes made by such method

DATE-ISSUED: December 2, 1997

## INVENTOR-INFORMATION

NAME	CITY	STATE	ZIP CODE	COUNTRY
Costa; Lawrence C.	Mansfield	MA		

## ASSIGNEE-INFORMATION

NAME	CITY	STATE	ZIP CODE	COUNTRY	TYPE CODE
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APPL-NO: 8 341496

DATE FILED: November 17, 1994

INT-CL: [6] BOLD 61/30, BOLD 67/30

US-CL-ISSUED: 210/650; 210/490; 210/500.38; 96/14; 95/45; 427/245

US-CL-CURRENT: 210/650; 210/490; 210/500.38; 427/245; 95/45; 96/14

FIELD-OF-SEARCH: 427/245; 427/246; 210/490; 210/500.37; 210/500.38; 210/500.41; 210/650; 210/651; 96/14; 264/45.1; 95/45

PRIOR-ART-DISCLOSED:

U.S. PATENT DOCUMENTS

☒ Search Selected☐ Search ALL



The Handbook of Industrial Membrane Technology. Marcel Dekker, Inc., New York, 1987, pp. 127-128.

Hille, G. et al., Angew. Chem., Int. Ed. Engl., 17, 1071 (1978) at 1071-1072.

Smirnov, E., Chemical Society Reviews, vol. 12, No. 2, 1983.

"4-Dialkylaminopyridines: Super Acylation Catalysts" at 129-131.

ART-UNIT: 19.

PRIMARY-EXAMINER: Dredge; Joseph W.

ATTY-AGENT-FIRM: Lippin & Kistner LLP

#### ABSTRACT:

The invention pertains to the polymerization of molecules having electrophilic and nucleophilic constituents on the same or different molecules, such polymerization initiated by aminopyridine catalysts which are substantially regenerated during polymerization. The invention also pertains to polymer products of such polymerization, to permselective membranes containing such polymers, and to processes and apparatus for separating fluids.

45 Claims, 2 Drawing figures

**WEST**

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**Search Results - Record(s) 11 through 16 of 16 returned**☐ 11 Document ID: US 6001889 A

LIT: Entry 11 of 16 File: USPT Oct 14, 1999

US-PAT-NO: 6,001,889

DOCUMENT-IDENTIFIER: US 60 1889 A

TITLE: Polymers with fractal structure

DATE-ISSUED: December 14, 1999

## INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Lefebvre; Michel S. M.	Kurrajong Heights			AUX

US-CL-CURRENT: 521/82

Full	Title	Citation	Front	Review	Classification	Date	Reference
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KWIC	Draw Desc	Image
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☐ 12 Document ID: US 5968585 A

LIT: Entry 12 of 16 File: USPT Oct 19, 1999

US-PAT-NO: 5968585

DOCUMENT-IDENTIFIER: US 5968585 A

TITLE: Process for recovery of protein from aqueous media in corn wet milling

DATE-ISSUED: October 19, 1999

## INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Liaw; Gin C.	Deeratur	IL		
Cheryan; Munir	Urbana	IL		

US-CL-CURRENT: 426/656, 210/641, 210/650, 210/651, 210/652, 426/478, 426/488, 426/629, 530/376, 530/377, 530/414

Full	Title	Citation	Front	Review	Classification	Date	Reference
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KWIC	Draw Desc	Image
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☐ 13 Document ID: US 5773076 A

LIT: Entry 13 of 16 File: USPT Oct 20, 1999





Full	Title	Citation	Front	Review	Classification	Date	Reference
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KWIC	Draw Desc	Image
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16 Document ID US 5147541 A

117: Entry 16 of 16

File USPT

Sep 15, 1992

US-PAT-NO: 5147541

DOCUMENT-IDENTIFIER: US 5147541 A

TITLE: Spiral filtration module with strengthened relaying leak and rein of constructing same

DATE ISSUED: September 15, 1992

## INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
McDermott, Jr., Thomas C.	Lynn	MA		
Skelton, Daniel F.	Billerica	MA		

US-CL-CURRENT: 211 321.74; 156 290, 210 321.83, 210 422.4, 421 157, 421 17, 421 170

Full	Title	Citation	Front	Review	Classification	Date	Reference
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KWIC	Draw Desc	Image
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## Terms

## Documents

116 and nanofiltration

16

Display

16 Documents, starting with Document: 16

Display Format: CIT Change Format